INFLUENCE OF BAROMETRIC PRESSURE
ON THE
DETERMINATION OF CIGARETTE SIDESTREAM-SMOKE

J.M. González and J. Sarabia

Centro de Investigación y Desarrollo; Tabacalera, S.A; Madrid; España

SUMMARY

An experiment was carried out in order to quantify the influence of barometric pressure on the determination of cigarette sidestream-smoke. Two different locations at 650 m and 10 m above sea level, respectively, and three different cigarettes, including commercial brands and the 1R4F reference cigarette, were selected for the experiment. A modified "fishtail" chimney device was used for the collection of sidestream smoke.

Results of mainstream deliveries confirmed previous research on the topic, showing significant differences in puff-count. Significant differences were also detected in some sidestream yields as a consequence of the influence of barometric pressure.

Two different chimney flow rates were investigated at the higher altitude laboratory in order to obtain the same sidestream yields as those obtained at the lower one. An increase in the flow rate was found to be a way to neutralize the influence of low barometric pressure.

INTRODUCTION

Barometric pressure is one of the conditions specified by ISO 4387 and ISO 3402 regarding the atmosphere of a smoking enclosure. The accepted range, according to ISO 3402, for barometric pressure in test atmospheres is from 860 to 1060 mbar, i.e. 645 to 795 torr. The lower limit of this range normally corresponds to an altitude of 1300 m above sea level.

Barometric pressure has a noticeable effect on the analytical smoking of cigarettes. As was established in a previous study, the lower the barometric pressure the higher the puff-count and the higher the debilitation of mainstream puffs (1).

The aim of this study was to examine the effect of barometric pressure - within the above mentioned accepted range - on the determination of cigarette sidestream-smoke.

EXPERIMENTAL SET UP

A test was planned in order to study the reproducibility of cigarette sidestream-smoke determination at two locations: Madrid and Sevilla at +650 m and +10 m above sea level, respectively, covering a range of barometric pressure from 690 to 755 torr. Obviously, Tabacalera's smoking analysis laboratory in Madrid was selected as a reference point, and another smoking laboratory was provisionally installed in the Quality Control laboratory of the Sevilla's cigarette factory as an alternative location.

Theree samples were selected including two commercial cigarettes: AB, an American-blend full-flavour cigarette; DAC, a dark air-cured cigarette; and the 1R4F reference cigarette. A summary of their typical mainstream yields

obtained in Madrid and their physical and dimensional characteristics can be observed in the Table 1 below.

TABLE 1 : Cigarette characteristics

		Samples	
	AB	DAC	1R4F
Total weight [mg]	1030	990	1090
Pressure drop [daPa]	110	115	135
Total length [mm]	84	79	84
Filter length [mm]	21	20	27
Tipping length [mm]	25	24	32
Butt length [mm]	29	28	35
Puff count [mm]	9.3	7.7	9.2
Smoke nicotine [mg/cig]	1.2	0.6	0.9
PMWNF [mg/cig]	17	11	10
Carbon monoxide [mg/cig]	15	15	12

All the samples and 44 mm Cambridge filters were conditioned at 22° C and 60 % relative humidity in Madrid. Then the cigarettes were hermetically sealed in groups of one hundred.

A schematic layout of the experimental set up is shown in Figure 1.

A portable four-ports Borgwaldt RM 4 CS smoking machine was selected in order to enable quick and easy installation. The small number of ports meant the performance of many smoking runs, but this smoking machine was preferred owing to its portability.

The well known "fish-tail" chimney device (2) was used for the collection of sidestream smoke. For this particular experiment a big chimney 120 mm wide at the lower opening and 500 mm long was modified in such way that a hinged plate could be positioned at a distance of 6 mm from the lower opening in order to avoid sidestream leakages. This also ensured that the cigarettes were smoked in a fresh air surrounding.

A Hewlett Packard gas-chromatograph with flame ionization, thermal conductivity and thermoionic detectors was used for the analyses of nicotine and water.

A Leyboldt Binos carbon monoxide-carbon dioxide analyzer, including a thermostabilized pump, was used for gas phase analysis - both, mainstream and sidestream -, and a Gillian Aircon high pressure-drop pump connected to a latex-made 250 litre bag was used for the collection of sidestream smoke. A Hewlett-Packard computer processed gas-phase data for noise and integration treatment on line.

Some auxiliary measuring apparatus such as an analytical balance (Mettler), a thermohygrometer (Lambretch), a barometer (Lambretch), an anemometer (Airflow) and a electronic bubble flow meter (Gillian) were used in both locations.

TABLE 2 : Experimental design parameters

# Samples	:	3
# Ports/smoking run	:	4
# Smoking processes/smoking run	:	3
# Cigarettes/port	:	3
# Cigarettes/smoking run	:	12
# Smoking runs/day	:	3
# Cigarettes/sample	:	36
# Days/location	:	3

Smoking schedule

Day	1	2	3
Run		Sample	
1	DAC	1R4F	AB
2	AB	DAC	1R4F
3	1R4F	AB	DAC

The experimental design parameters are shown in Table 2. 36 cigarettes were smoked per sample over three days as shown by the smoking run schedule that appears in the figure. CORESTA 10 was followed for the basic smoking specifications. A flow rate of 3.0 litres per minute was used for sidestream collection in Madrid and Sevilla. Additionally, a 3.5 litre per minute flow rate was also used in Madrid in order to bring the yields obtained in Madrid into line with the ones in Sevilla.

The cigarettes were lit using a gas lighter, and immediately the chimneys were lowered and the plates set in a horizontal position. As soon as the coal reached the butt length, the cigarettes were extinguished using water.

CORESTA 7 and 8 were followed for the analyses of nicotine and water in condensate collected by sidestream and mainstream filters. The chimneys were washed using 100 cm3 of solvent (2-propanol containing 0.1 mg/cm3 of quinaldine as internal standard). These solutions were analyzed using a gas-chromatographic method (column 25 m, 20 M Carbowax, 530 µm ; injector 250° C; nitrogen-phosphorus detector, 250° C; oven 170° C; carrier flow 15 cm3/min.) suitable for low nicotine concentrations. All chromatographic analyses were performed exactly one week after smoking at the C.I.D. facilities in Madrid. Blanks and standards were prepared for each smoking day.

The carbon monoxide-carbon dioxide analyzer was calibrated using standard carbon oxide/nitrogen mixtures of 0.1 and 0.2 % CO for sidestream, 2 and 5% CO for mainstream, 0.5 and 1 % CO_2 for sidestream and 5 and 10 % CO_2 for mainstream. Gas-phase analyses were performed just after finishing each smoking process, for sidestream, and immediately after each smoking run, for mainstream.

The nicotine-free dry condensate (PMWNF) deposited in chimneys was estimated using the tar/nicotine ratio method.

RESULTS AND DISCUSSION

A prior statistical treatment of results consisting of Dixon outlyer tests

was performed. Then t-tests were applied to the different comparisons of results, Madrid versus Sevilla. A summary of mainstream results is presented in Table 3.

The results showed increasing values of puff-count for all the samples investigated when the altitude increased, but no effect on this parameter was observed when the flow rate increased up to 3.5 litre per minute. On average, there was found to be a 3 % difference in puff-count within the ISO accepted range as some previous studies also showed.

Mainstream yields of nicotine and nicotine-free dry condensate are not significantly affected by this barometric pressure change, except for sample AB - probably due to a lack of uniformity. That means the per puff yields are lower for high-altitude smoking; in other words, mainstream smoke becomes smoother.

Mainstream gas-phase yields do not show significant differences except again in the AB sample. The CO and CO2 formation processes during the cigarette smoking are not very noticeably affected, as a whole, by barometric pressure within the studied range.

TABLE 3 : Puff-count and mainstream results

Sample	Location	Puff-count	Nicotine [mg/cig]	PMWNF [mg/cig]	CO [mg/cig]	CO2 [mg/cig]
AB	Sevilla	9.0	1.11	16.1	17	52
	Madrid (3.0)	9.2*	1.16**	16.8*	16	47**
	Madrid (3.5)	9.2*	1.12	16.6	16	49**
DAC	Sevilla	7.7	0.56	11.5	14	42
	Madrid (3.0)	8.1***	0.57	11.4	14	42
	Madrid (3.5)	8.1***	0.55	11.3	14	42
1R4F	Sevilla	9.1	0.94	11.6	12	43
	Madrid (3.0)	9.5***	0.96	11.6	12	41
	Madrid (3.5)	9.5***	0.95	11.5	12	43

* significant at 90 %; ** significant at 95 %; *** significant at 99 %

The summary of the sidestream results appears in Table 4.

The results of sidestream nicotine show significant differences when comparing Sevilla and Madrid yields at 3.0 litre per minute. The figures for nicotine are arrived at by adding nicotine collected on the sidestream Cambridge filter to nicotine deposited on chimney walls. On average, the difference observed is a 7 % for a 8.6 % change in barometric pressure. However, the differences are not significant when comparing Sevilla Madrid-3.5 litre per minute results.

Sidestream nicotine-free dry condensate yields are arrived at by adding condensate collected on the sidestream Cambridge filter to the estimation of that deposited on the chimney walls condensate. The results show again a significant difference of a 7 % on average between Sevilla and Madrid yields at 3.0 litre per minute. The results obtained in Madrid at 3.5

litre per minute are not significantly different from the Sevilla yields except for sample DAC.

Sidestream gas phase results do not reveal so significant differences either for CO or CO_2 yields, except for sample AB, between Madrid and Sevilla smoking. Values of CO and CO_2 by volume are certainly different, but the differences are lower when the results are expressed in weight units, taking into account the actual barometric pressure.

TABLE 4 : Sidestream results

Sample	Location	Nicotine [mg/cig]	PMWNF [mg/cig]	CO [mg/cig]	CO2 [mg/cig]
AB	Sevilla	4.90	33.0	62	506
	Madrid (3.0)	5.22***	34.6***	66**	504
	Madrid (3.5)	4.97	32.4	66**	518
DAC	Sevilla	2.24	26.4	57	406
	Madrid (3.0)	2.48***	29.2***	60*	419
	Madrid (3.5)	2.31	28.1**	60*	423*
1R4F	Sevilla	5.63	34.3	61	473
	Madrid (3.0)	5.98***	36.1***	60	478
	Madrid (3.5)	5.76	34.2	64**	491*

* significant at 90 %; ** significant at 95 %; *** significant at 99 %

As a summary, the most significant results were hence: (1) barometric pressure affects puff-count - i.e. cigarette burning - slightly but significantly; the lower the barometric pressure the slower the cigarette burning; and (2) an increase of 7 % in sidestream nicotine and PMWNF could be measured when barometric pressure decreased by 8.6 % and this variation could be "corrected" increasing the flow rate in the chimneys up to 3.5 litre per minute.

Obviously, the amount of oxygen available is lower at low barometric pressure and, consequently, the burning conditions of the cigarettes could be equivalent to a lower flow rate in the chimney. So, the increase of flow rate from 3.0 to 3.5 litre per minute in the chimney in order to "correct" the yield figures could be a practical way to compensate for the effect of lower oxygen available at low barometric pressure.

However, a closer examination of the results suggests other interpretation. The lower flow rate in the chimney could certainly affect the burning characteristics - as the puff-count observed-differences reveal - and condensation and coagulation of sidestream-smoke particles in such a way that an increase of sidestream-smoke yields is to be found (3,4). But, if the formation mechanisms of smoke particles could be affected by flow rate, the efficiency of the sidestream Cambridge filter could also be affected, as a consequence. All the main observations of this experiment on sidestream condensate, even the "corrected-by-flow" test, could be explained by a loss of efficiency in the sidestream Cambridge filter owing to modified flow and size distribution of sidestream-smoke particles. On the other hand, gas phase results show

2023118399

lower significance than the condensate ones. Under low oxygen atmosphere conditions, we could expect an increase in CO and a decrease in CO_2 by volume yields (5). That was observed, but the values expressed by weight - after taking account of barometric pressure and puff count - remain practically unchanged, suggesting a no so different burning conditions to explain the differences in sidestream condensate yields. All these considerations support the suspicion of an artifact of the sidestream collection method used, involving the filter efficiency in particular.

The sidestream condensate yield variations observed for different barometric pressures could be genuine, but the results of puff-count and sidestream CO and CO_2 make one think that some details of the method could be masking other factors affecting this experiment. Further investigation is necessary to demostrate if the sidestream Cambridge filters are equally efficient at collecting condensate at different barometric pressures.

CONCLUSIONS

1 Earlier results regarding the influence of barometric pressure on cigarette smoking are confirmed: the lower the barometric pressure the higher the puff-count, but no important differences are to be found in mainstream yields.

2 Gas-phase CO and CO_2 yields are not significantly affected by barometric pressure, either main- or sidestream.

3 An increase of 7 % in sidestream condensate yields is obtained when barometric pressure is 8.6 % lower.

4 Increasing the chimney flow rate is a practical way to compensate for the effect of low barometric pressure on sidestream condensate yields.

5 Further investigation would be necessary to clarify if the observed effect is genuine or a consenquence of a loss of efficiency in Cambridge filters when the barometric pressure increases.

BIBLIOGRAPHY

(1) González, J.M. and Sarabia, J.; "Influence of barometric pressure on the mechanical smoking of cigarettes" Paper presented at the CORESTA Congress in Guangzhou (1988).

(2) Proctor, C.J., Martin, C., Beven, J.L. and Dymond, H.F.; "Evaluation of an apparatus designed for the collection of sidestream tobacco smoke" Analyst 113 (1988) 1509-1513.

(3) Kaneki,K., Masuo, Y. and Okada, T.; "Determination of particulate matter and carbon oxides in sidestream smoke" Beitr. z. Tabakf. 14, 3 (1989) 155-162.

(4) Ishizu. Y., Ohta, K. and Tomita, H.; "Physical properties of tobacco smoke particles produced under different conditions" Beitr. z. Tabakf. 12, 3 (1984) 137-146.

(5) Baker, R.R.; "The formation of the oxides of carbon by the pyrolisis of tobacco" Beitr. z. Tabakf. 8, 1 (1975) 16-27.

2023118400

EXPERIMENTAL SET UP

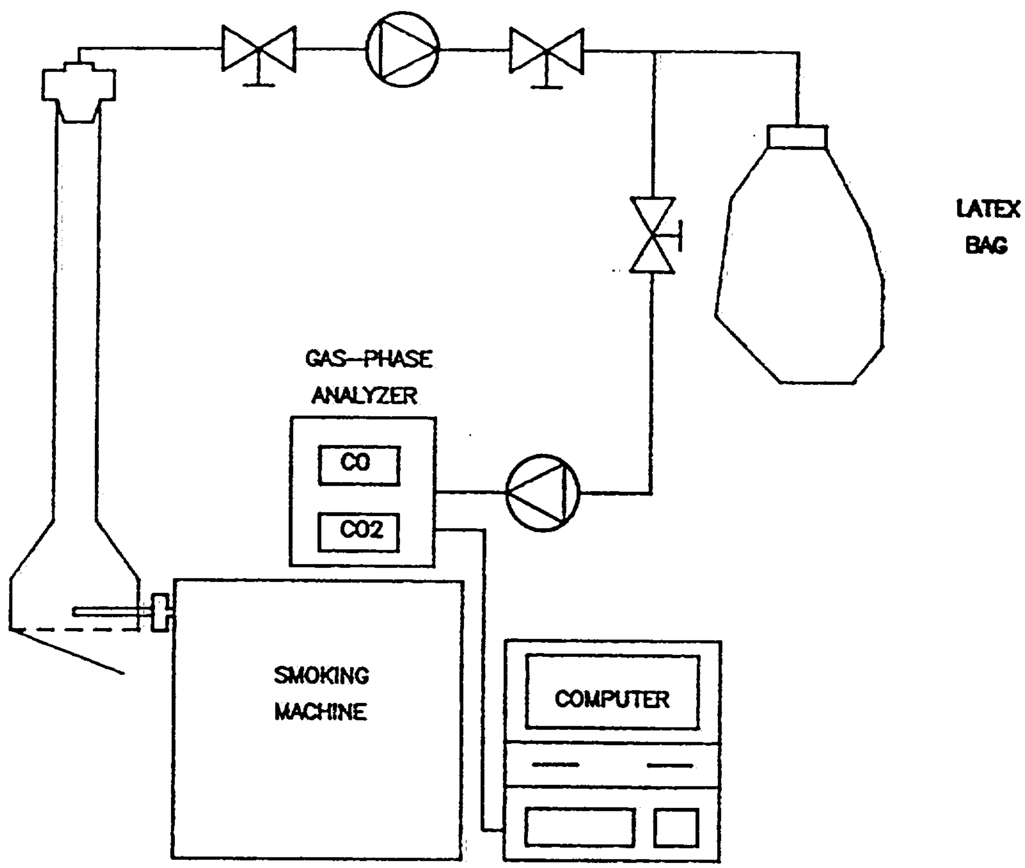

Figure 1

2023118401